Finite-size scaling at a topological quantum phase transition

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At quantum phase transition (QPT) properties of the ground state of the quantum system change drastically due to quantum fluctuations which are most clearly pronounced at zero temperature. Although many approaches have been proposed to examine QPTs, to locate critical points and to calculate values of critical exponents, an important question still remains: *Is it possible to explore the critical behavior of a system at QPT by examining the change of its ground state* $|\Psi_0\rangle$ *in a critical region, especially when there is no possibility to identify an order parameter nor to establish a pattern related to symmetry breaking?* Still, there exists a quest for new approaches, based on scaling and renormalization to search and characterize QPTs. We propose such an approach based on a topological charge Finite Size Scaling. We start by defining the topological charge: $\eta_T = \langle\Psi_0|W|\Psi_0\rangle/L$, with W being winding number and L - system size, respectively. Subsequently, the well-known quantum phase transition in the ground state of an antiferromagnetic spin-$\frac{1}{2}$ Heisenberg chain with nearest and next-nearest-neighbor interactions is re-investigated from this perspective. Finite Size Scaling of $\langle\Psi_0|W|\Psi_0\rangle$, $\langle\Psi_0|W|\partial_\lambda\Psi_0\rangle$, $\langle\partial_\lambda\Psi_0|W|\partial_\lambda\Psi_0\rangle$ leads to the accurate value of critical coupling $\lambda_c = 0.2412 \pm 0.0007$ and to the value of subleading critical exponent $\nu = 2.000 \pm 0.001$.